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DEVELOPMENT OF FAR INFRARED DETECTION TECHNIQUES

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I. INTRODUCTION

This grant supports the development of a variety of advanced far infrared detection techniques that will be used in future National Aeronautics and Space Administration (NASA) missions such as the Space Infrared Telescope Facility (SIRTF). These studies span the wavelength region $30\mu\text{m}$ to $200\mu\text{m}$ and include development of focal planes and electronics that would utilize them. Efforts reported here represent collaborations among the University of Arizona's Steward Observatory; Lawrence Berkeley Laboratories (LBL); and the University of California at Berkeley.

The overall goal of this program is to demonstrate extremely high performance detectors for low background applications between 30 and $200\mu\text{m}$. For the 40 - $120\mu\text{m}$ region, the program is developing a 32×32 filled detector array. Previous work has demonstrated the required performance with a Z-Plane array architecture; we are now upgrading construction facilities and techniques to increase yields and reliability. During this reporting period, we completed the initial tradeoff analysis for the interconnects between the detectors and readouts. We found satisfactory performance for both Flex-Cable and Tape Automated Bonding (TAB) devices, but analysis showed that an all-sapphire device would not meet our requirements. Further study of the two successful options will be conducted at Hughes Technology Center (HTC), leading to selection of the baseline approach during the next reporting period. In addition, the effort continued to develop readouts that can operate close to the detector element temperature; success would substantially improve the manufacturability of the arrays. For the 100 - $200\mu\text{m}$ range, previous work has demonstrated good performance with individual detector elements of stressed Ge:Ga; current efforts are to increase the quantum efficiency of these devices. Work continues to learn how to construct an alternate type of long wave detector, Ge:B Blocked Impurity Band devices. Following descoping of SIRTF, we are closing out the bolometer and refrigerator development. We documented the optical designs and approaches developed previously to meet the specific requirements of these detector types in terms of modulation of the signals for good photometric behavior within the constraints of a compact and self-contained cryogenic instrument. Further study was initiated for the Band 3 optical train, where we have concerns about complexity and the manufacturability of one component.

II. TECHNOLOGY DEVELOPMENT

A. General

With the completion of the "Ge:Ga Interconnect Tradeoff Analyses Report" (ITAP-0007, April 1993), we have concluded that there are no fundamental technological barriers prohibiting the use of either TAB or flex-cable interconnect in a cryogenic environment. Also, both technologies are readily available through a variety of suppliers ranging from large corporations to small specialty firms.

Throughout the effort, we have been sensitive to the qualification issue with both types of interconnects. We note that beyond numerous standards governing the design, manufacture, and testing of flex-cables, a host of studies have verified the operation of these cables in both static and dynamic cryogenic environments. We have also investigated the fact that standard TAB circuits are currently being mass produced under comparably rigorous manufacturing and design specifications. The TAB interconnect scheme remains to develop a "tailored" approach to reliability testing within a MIL-STD-883 framework.

To shift the focus from fundamental technological barrier elimination to design and manufacturing optimization, we have initiated a major subcontract for the development of a system optimized interconnect with Hughes Technology Center (HTC) in Carlsbad, CA. This effort will include considerable interplay with the current low temperature readout effort (NAS2-13768, "Development of Optimized Low-Temperature Readout", under the direction of Craig McCreight, NASA/Ames) underway at the same Hughes facility (see item B for further discussion). The initial demonstration of this beneficial interplay was the recommendation increased readout size and increased bond pad pitch for improved producibility for either interconnect.

Further initial system assessments include the suitability of either interconnect scheme to allow periodic heating of the readout to anneal out radiation damage from long term exposure in space and to remove other conditions that can lead to excess noise, and the design considerations dewar interface, which may require the interconnects to be elongated, asymmetrical, or angled to accommodate future 32x32 focal plane array (FPA) assembly constraints.

B. Readout Development

We participated in a design review of the Hughes Technology Center readout effort on March 12, 1993. Because of delays in getting a contract in place with HTC, this review was later than originally scheduled; however, because we agreed during this review on designs that minimized the number of masks and steps in the foundry, they felt that they could hold to the original delivery schedule. They presented detailed modeling of the various circuits. We agreed to have them reduce the gain (to $\sim 7 - 10$) of the cascode circuit to improve its dynamic range and linearity and to add a source follower readout with a single large input gate for each integrating amplifier to compare with their standard practice of dividing large gates into a number of segments. The rearrangement of input and output pads we had requested to make it easier to mount the readouts on interconnects has been incorporated by HTC in all readout layouts.

C. Band 3 Development

We informally monitored progress on Si:Sb arrays through contacts with IRS team members.

D. Ge:Ga Focal Planes

1. Flex-Cable

The second lot of cables (40 pieces) was received early in the reporting period. To secure this prompt delivery, the University of Arizona monitored both the cable manufacturer and the supporting processing subcontractors. Process development efforts in fine line etching and laser clearing resulted in good yield from this second lot.

Several 32 channel readout assemblies were assembled at the University of Arizona using these cables. Previously screened Amber AE-152 devices were integrated into the assemblies and characterized under a variety of test conditions. A small batch of these completed assemblies (along with an equal number of TAB interconnected assemblies) were designated to undergo a controlled set of tests in support of an interconnect tradeoff study which is reported in detail in ITAP-0007, "Ge:Ga Interconnect Tradeoff Analyses Report".

The thrust of this tradeoff analyses provided a careful review of design and manufacturing constraints, a performance evaluation, assessment of standards and qualification issues, and supplier and material availability reports allowed an interim evaluation of the flex-cable

interconnect technology. A key effort of the tradeoff analyses was to demonstrate the applicability of this type of interconnect in a cryogenic environment. To this end, a test program was established to assess performance before and after environmental testing.

Both survivability and functionality were measured with a sequence of tests that thermally, mechanically, and electrically stressed the assemblies. The test plan called for each style of interconnect assembly to undergo ambient electrical screen testing followed by numerous thermal cycles from ambient to 4.2K with additional electrical testing at 77K and 4.2K. Ambient temperature sine vibration sweeps to identify resonances were conducted. Thermal isolation was verified at 2K by measuring heater power versus readout temperature. Rapid thermal cycling dewars to allow a fast pump-down cycles, and a small vibration test system which allows both random and sinusoidal vibration of small components have been developed at the University of Arizona. The assemblies were tested with zero failures.

The functionality tests were defined as a series of tests performed to insure the proper behavior of the readouts on the interconnects. The four functionality tests were electrical operation, crosstalk, noise, and thermal isolation. For electrical functionality testing the baseline electrical operation of functional AE-152 readouts which are known, were compared to the operation of the AE-152 readout when mounted on the flex-cable interconnect. This testing of the flex-cable assembly revealed fully functional readouts after numerous assembly procedures and handling. The thermal isolation testing part of the trade study is key in verifying the balance between optimum detector performance and elevated readout operating temperature. Each interconnect assembly appeared to be isolated sufficiently to facilitate heating the readout to a good operating temperature during helium temperature testing. The assembly was functioning properly when approximately 1/2 mW of heater power was applied, which is well within specifications.

Additional efforts in the reporting period include initial support of a major subcontract with (HTC) to evaluate current interconnect products, and design and manufacture of future generations of interconnects. Plans for the next reporting period will concentrate of fabrication of numerous full compliment 1x32 assemblies to support stacking development and imaging testing.

2. TAB

As discussed last reporting period, fewer than expected TAB inner lead bonded assemblies were received from the supplier. This was primarily due to the exhaustive process development for the surface treatment using up most of the assets. Nevertheless, the units that were received were

inspected, tested, and integrated into the readout assembly for the trade study testing. As with the flex-cable interconnects, these TAB interconnects also passed the complete test cycle with no failures. Minor differences were observed with the TAB interconnect such as slightly less rigidity and slightly higher power dissipation, but no fundamental problem was uncovered.

In support of the initial efforts for the HTC, it was decided not to procure an additional lot of prototype TAB interconnected readout assemblies as reported in the previous progress report. This was based on two reasons, the first being the fact that late in the reporting period HTC was briefed on our efforts with the interconnect development for both the TAB and the flex-cable, and the fact that HTC is one of the divisions of Hughes that specializes in TAB equipment, the other being Hughes Irvine.

It was felt that after the subcontract commences next reporting period, HTC will have had an opportunity to provide a detailed analysis of whether or not HTC internal processes are available for TAB tape manufacture.

3. Sapphire

In anticipation of the low temperature readout, preliminary layouts and thermal modeling were conducted to examine the effect of the potential readout annealing cycle on an all sapphire substrate FPA architecture. Figure 1 shows the basic layout using 50 μ m thick sapphire, the 32 channel detector array, and the supporting, outline structure of molybdenum alloy. It was determined that wherever the thermal anchor points were on the assembly, the detector operating temperature was not violated due to the excellent thermal conductivity of sapphire at 2K.

As discussed in previous reports, the handling during normal assembly processes remains a key issue to overcome. To try and understand basic limits with regard to this issue, 75 μ m thick sapphire substrates were procured metallized, and patterning is underway. It is planned for the next reporting period that these substrates will be integrated into a one piece frame structures for initial thermal cycling.

E. Stressed Ge:Ga

The experiment described in the previous quarter to mount stressed detectors between sapphire pads has been completed. Sapphire has a good match of thermal contraction with germanium, and we hoped that the resulting reduction in lateral stress on the contacts would result in better

noise performance. These hopes were not realized.

A variety of concepts for stressing harnesses for arrays were proposed for more detailed evaluation to occur in the following quarter.

F. Ge BIBs

The Ge BIB effort at LBL has been on hold, waiting for Gerhardt Penzel (Erlangen, Nuremburg) to complete preparations and carry out high energy boron implants in germanium.

G. Bolometers

Work continued on the two papers for the SPIE meeting in Orlando, April 12-16, 1993.

H. Optical Concepts

The preliminary optical concept for MIPS was described in a ITAP-0006, "Initial Optical Concept for MIPS Atlas IIas Configuration", February 1993, written by Craig Thompson and Debbie Wilson. This report gives full optical prescriptions for each band as well as general layout diagrams and a narrative on the operation of the optical system. The optical prescriptions were reviewed at Ball Aerospace by Bob Woodruff and discrepancies (which were all in the area of notation and definitions) were resolved. Woodruff's review found no problems with the optical concept.

We carried out an informal survey of the manufacturability of the optical elements required for the MIPS conceptual design. Although all the elements were found to be manufacturable, the large re-imaging mirror for Band 3 would be a specialty item and might be obtainable at present only through the diamond milling capability at Lawrence Livermore Laboratories. It is marginally compatible with other diamond turning facilities that use lathes. Although this situation is likely to change for the better as more ambitious diamond turning facilities are put into place, we find it worrisome. In addition, the Band 3 optical train is significantly more complex than the trains feeding the other bands in the instrument. Because of these considerations, we initiated a study of Band 3 at Ball Aerospace to determine if a simpler and more manufacturable concept could be found.

I. Scan Mirror

Ball Aerospace conducted a tradeoff analysis of approaches to meeting our requirements for a scan mirror. This work was reviewed at Ball on March 24, 1993. They recommended a mechanism similar to the scan mirror developed in the Netherlands for the ISO Short Wavelength Spectrometer (SWS). However, we also agreed on a number of modifications in this mechanism to meet our requirements. First, the mechanical mounting of the SWS design needs minor modification to make the mirror package properly in our instrument without having its base interfere with our filter wheel. Second, to minimize power dissipation, we plan to wind the motor coils with wire of copper with strands of embedded superconductor. This wire is available commercially and should allow the scan mirror to operate at room temperature, when the copper will carry the current, but should reduce power dissipation virtually to zero at helium temperatures. Third, we plan to replace the Linear Variable Differential Transformer (LVDT) used as a position sensor in SWS with a Differential Inductance Transducer (DIT) developed at Ball. There are two advantages gained by this change: 1) the DIT has much lower power dissipation than the LVDT; and 2) DITs will be used elsewhere in MIPS and other SIRTf instruments, whereas the LVDT would have been a unique transducer in SIRTf.

We agreed to approach the SWS team to obtain more detailed information on their mechanism so Ball could use the original plans as the starting point for the modified design.

Thin Sapphire Structure

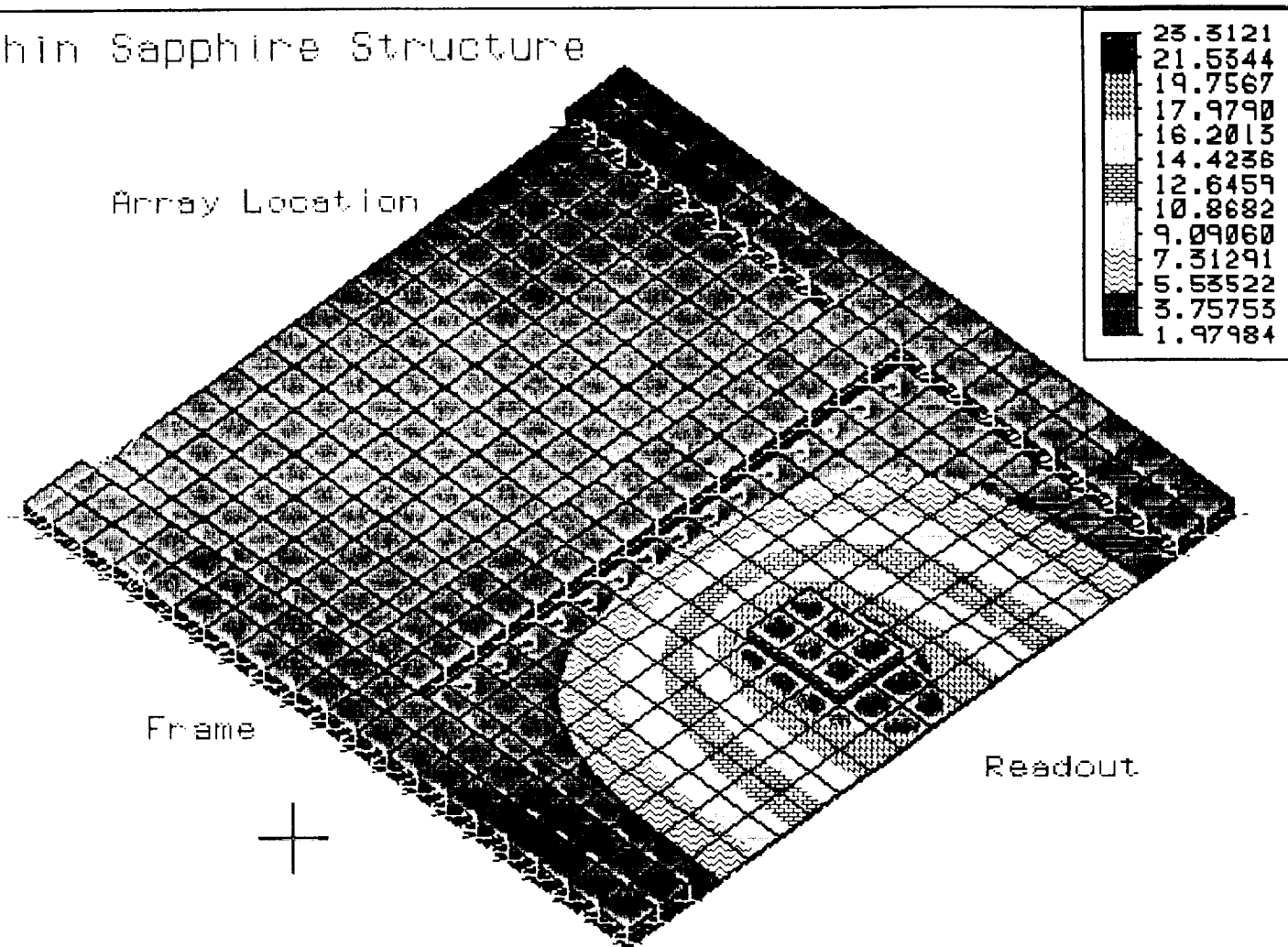


Figure 1 Thin Sapphire Structure